

# Voltage-To-Current Converter Works From A Single-Supply Rail

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Voltage-to-current converters feeding to grounded loads often find their way into industrial measurements and control applications. The conventional textbook circuit needs both positive and negative-supply rails (Fig. 1). In this circuit:

$$e_{in} - e_1 = I_L R_S$$

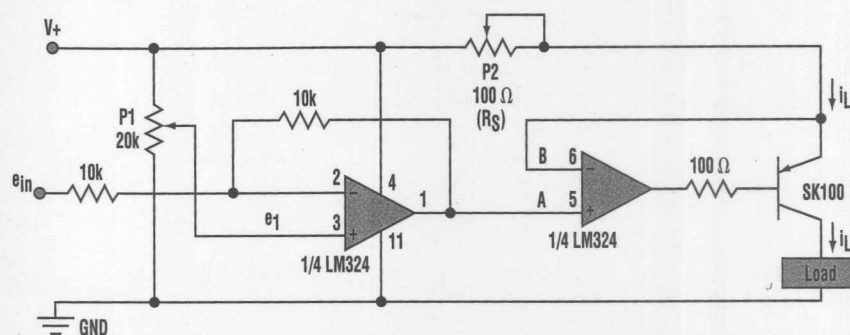
Therefore, the load current is:

$$I_L = e_{in}/R_S - e_1/R_S$$

The first term is proportional to the input voltage  $e_{in}$ , and the second term is a constant. Here,  $e_1$  is derived from the negative power-supply rail through a potentiometer:

$$I_L = e_{in}/R_S + (-e_1)/R_S$$

$R_S$  is selected so that the first term gives 16 mA for full-scale input voltage, and the potentiometer is adjusted so that the second term provides a constant 4 mA. In effect, the output ranges from 4 to 20 mA, corresponding with zero to full input voltage. But failure of the negative power supply causes error-



**2. An alternate circuit provides between 4 and 20 mA of output corresponding to 0- to 1-V input. It uses only a positive supply (typical  $V^+ = 15$  V). Adjust P1 for zero (4 mA) and P2 for span (20 mA). Load resistance can reach 500  $\Omega$  without saturation. Replace the transistor with a Darlington pair to reduce signal inaccuracy caused by the transistor's base current.**

neous output. Moreover, there may be equipment where the negative power supply is not available, requiring generation just for this application.

In such cases, there's a slightly different circuit that works on a single-supply rail (Fig. 2). This circuit uses one half of the quad operational amplifier LM324. The first amplifier is configured as a subtractor, while the second amplifier is configured as a current converter.

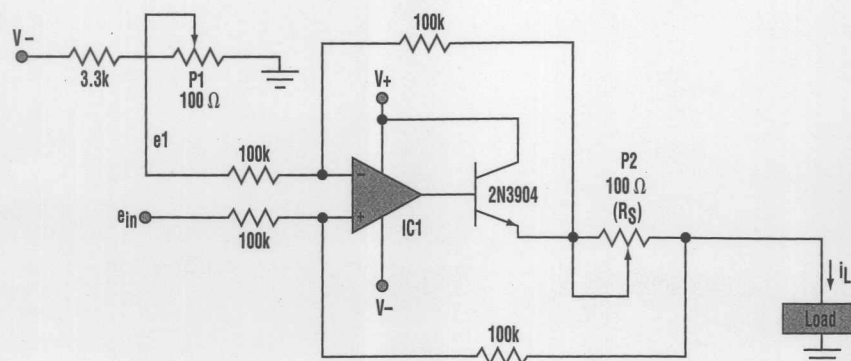
The output of the first amplifier at A equals  $e_1$  minus  $e_{in}$ . Here,  $e_1$  is derived from the positive power supply by potentiometer P1. The voltage at B equals V minus  $I_L R_S$ .

Op amp inputs at A and B are the same, so:

$$e_1 - e_{in} = V - I_L R_S$$

$$I_L = e_{in}/R_S + (V - e_1)/R_S$$

The first term is proportional to the input voltage, with the second term a constant.  $R_S$  is chosen so that the first term gives 16 mA for full-scale input voltage, and the potentiometer is adjusted such that the second term supplies a constant 4 mA. In effect, the output is 4 to 20 mA, corresponding to zero to full input voltage. Thus, this circuit works without using a negative power-supply rail. For the circuit shown in Figure 2, the current varies from 4 to 20 mA with an input of 0 to 1 V.



**1. This conventional circuit gives 4 to 20 mA of output for an input of 0 to 1 V. First adjust P1 for zero (4 mA), then P2 for span (20 mA). The circuit needs a positive and a negative supply. Typical power supply voltages are  $\pm 15$  V.**

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